



Country Economics Department  
The World Bank  
March 1991  
WPS 638

# **Researching the Trade-Productivity Link**

## **New Directions**

**James Tybout**

No stable, predictable correlations have emerged in studies of how trade policy affects productivity growth but market concentration seems to be an important factor. Research also suggests that increased foreign competition tends to induce cuts in plant size, may improve technical efficiency, and appears not to be closely linked with firm entry patterns.

This paper — a product of the Trade Policy Division, Country Economics Department — is part of a PRE research project, Industrial Competition, Productive Efficiency, and Trade (RPO 674-46). Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Dawn Ballantyne, room N10-023, extension 37947 (58 pages).

Tybout reviews the literature linking trade policy and productivity. He finds that:

- The literature on X-efficiency argues that exposure to foreign competition induces managers to make an extra effort to eliminate inefficiency, but makes fragile assumptions about the labor supply and changes in work incentives.

- The literature on economies of scale argues that when domestic firms enjoy market power, extra competition from foreign producers can force producers to expand or exit — but the net effect of liberalization depends on demand shifts, ease of entry or exit, and the nature of competition.

- Arguments involving technological catch-up are equally fragile. Uncertainty can lead producers to place a premium on flexibility that may mean sacrificing some productivity.

It is a mistake to think of productivity growth as an orderly shift in technology, says Tybout. Rather, the processes of learning, innovation, investment, entry, and exit are what matters. Trade orientation affects these processes through many channels, often by influencing entrepreneurial ability to monitor new technological developments or by changing the expected returns from innovation.

Figures on productivity should be approached with skepticism, he concludes. Problems of measurement error, disequilibria, and aggregation bias can easily create the illusion of trends and correlations that have no basis in the economic processes we hope to capture. But Tybout reports on two new directions in thinking about productivity growth.

The first is concerned with salvaging sectoral- and industry-level calculations by correcting for scale economies, adjustment costs, or noncompetitive

pricing. These approaches still suffer significant measurement problems and aggregation bias, but give some sense of the robustness of growth series to violations of traditional assumptions.

The second new direction concerns how plant heterogeneity shapes sectoral productivity growth. New techniques from this infant (except for work on efficiency) field give a crude sense of the importance of entry, exit, and heterogeneity in shaping productivity growth patterns and some specifics on the nature of aggregation bias in industry studies.

Tybout concludes that no stable, predictable correlations have emerged, although in some countries and subperiods there is some association between trade flow patterns and indices of productivity growth at the industry level, even after correcting for several measurement problems. The effects of trade regimes on productivity growth seem to be related to market concentration, although the nature of this association is unstable.

Patterns of industrial evolution show a surprising diversity. In some economies, much of output fluctuation seems to come from the creation and death of plants; in others, size adjustments by incumbent plants are what matter. Further, there are systematic productivity differences between entering, dying, and continuing plants. So turnover patterns play an important role in shaping productivity differences.

The Bank's Industrial Competition, Productive Efficiency, and Trade project focuses on linking entry, exit, and adjustments in scale and technical efficiency with exposure to a particular trade regime. So far it appears that exposure to more foreign competition is not closely linked with patterns of firm entry, tends to induce reductions in plant size, and may cause some improvements in technical efficiency.

The PRE Working Paper Series disseminates the findings of work under way in the Bank's Policy, Research, and External Affairs Complex. An objective of the series is to get these findings out quickly, even if presentations are less than fully polished. The findings, interpretations, and conclusions in these papers do not necessarily represent official Bank policy.

Researching the Trade/Productivity Link:  
New Directions\*

by  
James R. Tybout

Table of Contents

I.	Overview	2
II.	The Theory of Productivity Growth and Its Link to Trade	2
	A. Deterministic Models	3
	B. Technological Catch-up	4
	C. The Role of Uncertainty	5
	D. Trade Regimes and Long Run Growth	6
III.	Sectoral/Industry Level Approaches to Productivity Measurement	8
	A. Traditional Residual-based Calculations	8
	B. Modern Refinements of Residual-based Calculations	14
	1) Constant Returns to Scale	14
	2) All Factors are Freely Adjusted	18
	3) Competitive Behavior	21
IV.	Micro Approaches to Productivity Measurement	28
	A. Heterogeneity and Productivity Growth: An Overview	29
	B. Trade, Entry, and Exit	39
	C. The Size Distribution of Plants	41
	D. Plant-specific Technologies	47
V.	Concluding Remarks	50
	A. Productivity Measurement	50
	B. Linking Trade Regimes and Productivity	51
	Bibliography	53

\* This paper was prepared under funding from the World Bank research project, Industrial Competition, Productive Efficiency, and their Relation to Trade Regimes (RPO 674-46). The author has benefited from the comments of Bela Balassa, Ricardo Caballero, Ann Harrison, Jaime de Melo, and Mark Roberts.

## **I. OVERVIEW**

This paper is an effort to bring together diverse literatures on the measurement of productivity and its relation to trade regime, focussing on recently developed techniques and their application. Section II provides a brief review of the theoretical arguments linking trade policy and productivity. Empirical work at the sector and macro level is discussed in section III, and plant level empirical work is discussed in section IV. Throughout these latter two sections, applications of the different approaches are reported to a sample of semi-industrialized countries that have recently been analysed in the World Bank research project "Industrial Competition, Productivity, and their Relation to Trade Regimes," hereafter the ICPT project.

## **II. THE THEORY OF PRODUCTIVITY GROWTH AND ITS LINK TO TRADE**

In trade models that presume perfect competition, "opening up" generally improves the allocation of factors across sectors, and thereby induces a one time increase in the value of domestic production. However, liberalization does not reduce the volume of inputs needed to produce a given bundle of outputs. Thus, although many economists believe that there are important linkages between trade regimes and factor productivity, they have had to look elsewhere for formal models that support their priors. This section provides a brief review of the arguments that have emerged, devoting special attention to theoretical developments of the past decade.

#### A. Deterministic Models

To development economists, perhaps the best known attempts to link trade policy and productivity are based on "X-efficiency" arguments. The more rigorous contributions to this literature establish that trade liberalization can change the opportunity cost of leisure in such a way that managers work harder. That is, the return to entrepreneurial effort is increased by exposure to foreign competition, inducing managers to make an extra effort at eliminating inefficiency (e.g., Corden, 1974; Martin and Page, 1983). Weaknesses of this argument are discussed in Corden (1974) and Rodrik (1988a): it requires that the entrepreneurial labor supply curve is upward sloping in the relevant range, and that changes in work incentives go in the same direction for both export-oriented and import-substituting producers.

Arguments based on increasing returns are also common in the development literature. Page and Nishimizu (forthcoming) summarize the logic as it has often appeared: "The existence of economies of scale . . . implies that a widening of the market through trade should lead to reductions in real production costs. In the context of an output-oriented development strategy, this argument is usually cast in terms of the benefits of increased demand through export expansion . . . ." In the past decade this notion has received closer scrutiny in the analytical literature that treats trade under imperfect competition. There it has been shown that when domestic firms enjoy market power, extra competition from foreign producers can force producers to expand or exit.<sup>1</sup> However, as with the X-efficiency arguments, these effects are not

---

<sup>1</sup> Relevant summaries include Krugman (1986), Rodrik (1988b), and Roberts and Tybout (1990a).

unambiguous. The net effect of liberalization on productivity depends upon the specifics of the demand shifts that accompany liberalization, ease of entry or exit, and the nature of competition.

## B. Technological Catch-up

Formal models that relate trade regimes to technological modernization have also begun to appear. For example, Rodrik (1988a) develops a framework in which the representative firm's rate of "catch-up" to international productivity levels depends positively on its market share. Trade reforms therefore are likely to slow down the transition to state-of-the-art technologies in import-competing sectors, and accelerate the transition among exportables. In an alternative formulation, Rodrik (1988a) argues that one way domestic producers compete is through choice of technique. Hence producers may tacitly collude when protected from foreign competition by failing to modernize their plants, and trade liberalization may induce defection from the collusive equilibrium. Like all the arguments listed thus far, this one is fragile. The direction of the effect depends upon relatively arbitrary assumptions.

Although they do not usually consider the role of trade policy per se, formal models of the technological diffusion process are relevant as well. For example, Jovanovic and Lach (1989) provide an analytical framework in which experience acquired through production leads to publicly observed improvements in technology. Hence entrepreneurs who wait to enter a new line of production will be able to embody relatively advanced techniques in their capital. On the other hand, if they enter early, few will be producing the new product, and output prices will be high. The rate of technological

diffusion is determined so as to exactly offset these two considerations, making the time at which one enters the new product market a matter of indifference. Presumably by shifting the demand curve for products that involve new productive processes, and by affecting expectations regarding future demand, trade policy influences the balance between these two forces.

### C. The Role of Uncertainty

Trade policy affects the tightness of the link between domestic and world markets, and generates speculation about its own sustainability. Accordingly, trade reforms can change entrepreneurial uncertainty regarding future economic conditions, creating further productivity effects. For example, given the presence of sunk entry or exit costs, increased uncertainty should reduce the amount of entry and exit associated with given changes in observable variables (Dixit, 1989a, 1989b; Baldwin and Krugman, 1989; Baldwin, 1989). So unsustainable trade reforms are likely to generate relatively little change in the mix of productive capacity; most output adjustment will come from changing production levels at existing facilities. On the other hand, reforms that establish a credible, stable regime may induce rapid adjustments in the volume and capabilities of industrial capital.

Additional predictions emerge when a menu of alternative technologies is available to each potential market entrant. For example, entrepreneurs are likely to favor low sunk-cost techniques when uncertainty about future market conditions is high (Lambson, 1989). Accordingly, high uncertainty may lead to labor-intensive technologies, even though more capital-intensive technologies would be less costly to operate if market conditions were stable. Sunk costs that differ across technologies are not critical for this type of result.

Imagine a choice between two alternative plants that can be acquired for the same price. The first plant has one large machine that is very efficient when combined with 10 workers but much less so when combined with fewer or more; the second has 10 small, identical machines, each of which can be operated at capacity with one worker. The first plant may produce more than the second when operated at optimal capacity, but the second technology may be preferable when demand fluctuations are large and unpredictable -- it implies a flatter average cost schedule, which can mean lower expected costs. In short, regimes that inspire producers to place a premium on flexibility may lead to some sacrifice in terms of productivity.

#### D. Trade Regimes and Long Run Growth

None of the frameworks mentioned above establishes why trade policy might affect long run growth rates in output or productivity. Several alternative approaches provide such a link. One venerable strand of the development literature begins from the premise that new processes diffuse through an industry as managers learn of them and older vintage machines depreciate, so there is no single production function. This means it is a mistake to think of productivity growth as an orderly shift in technology; rather, the processes of learning, innovation, investment, entry, and exit are what matter. Trade orientation affects these processes through many channels, often by influencing entrepreneurial ability to monitor new technological developments and/or by changing the expected returns from innovation. Stewart and Ghani (1990) provide a useful review of the conceptual and empirical studies relevant to developing countries.



A second literature is less sweeping in scope but analytically more explicit about the role of learning externalities. One example is provided by Lucas (1988), who shows how learning-by-doing externalities at the sector level create a link between trade policy and long run growth patterns through induced shifts in the sectoral composition of output. Grossman and Helpman (1989, 1990) explore another, related mechanism. They assume that research and development (R&D) generates public knowledge as well as private appropriable returns.<sup>2</sup> Entrepreneurs reap these returns by developing new varieties of intermediate goods, and the link to growth is completed by the dependence of final good productivity on the menu of intermediates available.<sup>3</sup> (The richer the menu, the closer final goods producers can get to their ideal input mix.) Trade policy affects the rate at which productivity growth takes place in this world for several reasons. First, when deciding whether to develop new products, entrepreneurs consider the variety of substitute products already available, which depends in turn upon their exposure to international competition and the ease with which knowledge crosses international boundaries. Second, in larger markets there is more demand for any particular new product variety, so ceteris paribus, market size encourages innovation. These two effects can work against one another, making the net impact of integrating with world markets ambiguous.<sup>4</sup> Finally, new product

---

<sup>2</sup> For a more detailed summary of Grossman and Helpman (1989a and 1989b), see Helpman (1990).

<sup>3</sup> In Grossman and Helpman (1989b) the industrialized countries develop new products, and the developing countries investing in "de-engineering" them. This variant of the basic structure allows for product cycle effects.

<sup>4</sup> For example, it is possible that a small country might actually slow its growth rate by opening. However, it is important to keep in mind the distinction between growth effects and welfare effects. Welfare may improve

development requires labor and capital inputs, which are also used in the production of traded goods. So a change in trade regime that affects relative output prices also affects the returns to new product development (through Stolper/Samuelson linkages), and thereby influences the rate of productivity growth.

### III. SECTORAL/INDUSTRY LEVEL APPROACHES TO PRODUCTIVITY MEASUREMENT

As the discussion above makes clear, there are many potential linkages between trade and productivity. It is not at all obvious which ones are empirically relevant, much less what their net effect will be in a particular liberalization episode. Accordingly, considerable attention has focussed on empirical research. This section selectively reviews the techniques that have been used to measure productivity with sectoral or industry level data, and reports some recent applications.

#### A. Traditional Residual-based Calculations

The most common approach to productivity measurement begins by assuming a neoclassical production function at the sectoral or industry level:

$$(1) \quad Y = f(v, t)$$

Here total output ( $Y$ ) is a concave function of the vector of inputs ( $v_k \times 1$ ) and a time index ( $t$ ) that allows the function to shift with technological innovations or improvements in the efficiency of existing technologies. The

---

even as growth in output and productivity are slowing.

elasticity of output with respect to time,  $\epsilon_{Y,t} = (\partial f / \partial t) / Y$ , is hereafter referred to as total factor productivity (TFP) growth.

The role of TFP growth is typically isolated by expressing (1) in growth terms, and rearranging:

$$(2) \quad \epsilon_{Y,t} = \dot{Y}/Y - \sum_{j=1}^k \theta_j (\dot{v}_j/v_j)$$

Here dots denote total derivatives with respect to time, and  $\theta_j = (\partial f / \partial v_j)(v_j/Y)$  is the elasticity of output with respect to the  $j^{\text{th}}$  factor input. Then, assuming that factors are paid the value of their marginal product ( $w_j = P \partial f / \partial v_j$ ), one may replace output elasticities with factor shares ( $s_j = w_j v_j / PY$ ) and estimate of TFP growth using a Divisia index:

$$(3) \quad \hat{\epsilon}_{Y,t} = \dot{Y}/Y - \sum_{j=1}^k s_j (\dot{v}_j/v_j)$$

The "hat" on  $\epsilon_{Y,t}$  indicates that this is an estimator, and implementation requires that instantaneous time derivatives be replaced with discrete changes.<sup>5</sup> In the more involved applications, diverse types of labor, capital

---

<sup>5</sup> Shares  $s_j$  become averages of current and previous period shares. The resultant measure of TFP growth, known as a Tornqvist index, yields the exact rate of productivity growth only when the underlying technology is linear homogeneous translog. Alternative indices based on Taylor series expansions are more robust with respect to functional form, but the added accuracy is likely to be small for temporal comparisons within a given industry or country (Denny and Fuss, 1983).

and intermediates are aggregated using Tornqvist indices, and changes in the quality of each factor are analyzed.<sup>6</sup>

Given the possible linkages between trade regime and productivity growth, it has often been asked whether TFP growth calculations based on equation (3) correlate with exposure to foreign competition. Much of this literature is surveyed elsewhere (Chenery *et al.*, 1986; World Bank, 1987; Pack, 1988; Havyrlyshyn, 1990), so I limit myself here to a few summary remarks. First, although many cross-country studies find that rapid output growth is associated with rapid export growth or high export to output ratios, it is less common to find that rapid TFP growth (as measured by equation 3) correlates positively with openness.<sup>7</sup> Second, another set of studies examines the within-country temporal correlation of openness and TFP growth. This approach has the advantage of controlling for country-specific effects that might otherwise obscure matters, and comes closer to revealing the productivity gains that a given country contemplating trade reforms could reasonably expect to reap. However, although some of these studies conclude there is a positive association between export growth and productivity (e.g., Krueger and Tuncer, 1982; Nishimizu and Robinson, 1984; Nishimizu and Page, forthcoming), Pack (1988) and Havyrlyshyn (1990) both arrive at the conclusion that there is no strong evidence in favor of such a linkage. Third, in their multi-country study of industry-level TFP indices, Nishimizu and Page

---

<sup>6</sup> For a recent demonstration see Jorgenson *et al.* (1987).

<sup>7</sup> Pack (1988) writes that "[c]omparisons of total factor productivity growth among countries pursuing different international trade orientations do not reveal systematic differences in productivity growth in manufacturing, . . . ." However, Chenery *et al.* (1986), Balassa (1985), and Edwards (1989) have found a positive association between TFP growth and openness.

(forthcoming) find that other dimensions of policy significantly influence the relation between trade and productivity. Specifically, the manner in which domestic producers are protected (e.g., QRs versus tariffs) and the market orientation of the economy (laissez faire vs. socialist/populist) both matter.

As a first step in researching the trade/productivity link, each author preparing a country study for the ICPT World Bank research project was asked to perform regressions in the spirit of the Nishimizu and Robinson model. Table 1 summarizes the findings. For each country, annual observations on three-digit industries constitute the units of observation. TFP growth rates are constructed using equation (3) after putting all variables in constant prices. These growth rates are explained with the components of a demand-side sources of growth decomposition (domestic market growth, import substitution, and export expansion), a Herfindahl index of concentration, and an interaction term that allows the effects of import penetration to vary with concentration.<sup>8</sup> The latter two terms allow for market structure effects like those discussed in Rodrik (1988) -- they are a novelty of the ICPT specification. Industry dummies and annual time dummies are included in all regressions but not reported.<sup>9</sup>

---

<sup>8</sup> Let  $X$  be the level of exports and  $M$  be the level of imports. Then the size of the domestic market is  $D = Y + M - X$ , the fraction of the market serviced by domestic producers is  $u = (Y - X)/D$ , and output growth can be decomposed by destination (i.e., by demand-side source of growth):

$$\dot{Y}/Y = (uD/Y)(\dot{D}/D) + (uD/Y)(\dot{u}/u) + (X/Y)(\dot{X}/X)$$

The first term reflects domestic market expansion, the second reflects import substitution, and the third reflects export growth (e.g., Chenery *et al.*, 1986).

<sup>9</sup> It would be preferable to have separate regressions for each industry, but our panels do not span enough years to permit this.

Table 1: Explaining TFP Growth, Pooled Data from 3-Digit Industries\*

	<u>Chile</u> (79-86)	<u>Colombia</u> (77-87)	<u>Turkey</u> (76-85)	<u>Morocco</u> (84-88)
Intercept	-.090 (.061)	-.024 (.032)	.030 (.60)	-.118 (.197)
Domestic Dmd. (X <sub>1</sub> )	.178* (.040)	.362* (.047)	.47* (.045)	.008* (.004)
Import Subs. (X <sub>2</sub> )	.322* (.119)	-.034 (.113)	.44* (.075)	.132* (.005)
Export Expan. (X <sub>3</sub> )	.465* (.154)	.330* (.095)	.47* (.134)	.002* (.001)
Herfindahl (X <sub>4</sub> )	.787 (.401)	.004 (.289)	--	-.180 (1.25)
Interaction (X <sub>2</sub> *X <sub>4</sub> )	-1.63* (.413)	2.79 <sup>c</sup> (1.04)	--	-.504* (.189)
Mean Dep. Var.	-.012	-.008		.057
$\bar{R}^2$	.266	.303	.494	.474
F statistic	2.89	3.92	7.17	2.96

\* Annual time dummies and three-digit industry dummies were included in all regressions but are not reported. Turkish figures refer to the private sector only; in other countries the public manufacturing sector accounts for less than 5 percent of the plants.

The clearest determinant of TFP growth is a familiar one: output expansion. This positive correlation between the components of output growth ( $X_1$ ,  $X_2$ , and  $X_3$ ) and measured productivity, known as Verdoorn's Law, is sometimes taken to reflect embodiment of new technologies during periods of rapid investment and/or scale economies (e.g., Chenery et al, 1986; Nishimizu and Page, forthcoming). It may also simply reflect measurement problems due to price deflators and aggregation bias. Any measurement error in output growth will cause output growth and Tornqvist indices of TFP growth to be correlated, so domestic demand expansion may exhibit spurious positive correlation with TFP, and import substitution may exhibit spurious negative correlation (refer to footnote 8). Moreover, even when output growth is measured without error, there are several reasons to expect that TFP growth figures based on equation (3) are biased by an amount that is correlated with fluctuations in output. We will return to this point shortly.

Notice next that it appears to matter whether demand expands because of domestic market growth, export growth, or import substitution, but the pattern is country specific. This may simply reflect differing degrees of measurement error in output growth relative to total output variation. However, this is not likely to explain the fact that import substitution has a larger positive effect on productivity than domestic output growth in two of the countries, evaluating the equations at Herfindahl values of zero. Nor does it seem to explain the importance of industry concentration in conditioning the relation between import substitution and growth. In two of the countries (Chile and Morocco), import substitution has a significantly smaller effect on productivity growth in concentrated industries. On the other hand, in Colombia, import substitution is associated with especially high productivity

growth in concentrated industries. Taken together, the results suggest that market structure does affect the nature of the linkage between trade patterns and productivity, but the relationship is not a stable one.

## B. Modern Refinements of Residual-Based Calculations

Even when data are observed without error, the following assumptions are necessary in order to view calculations based on equation (3) as truly reflecting productivity growth: (a) there are constant returns to scale; (b) all factors are freely adjusted to maximize profits; (c) markets are competitive; and (d) all plants employ identical technologies. None of these assumptions is innocuous, and each has been an area of active research in the past decade. This subsection reviews the problems created when the assumptions are violated, and describes possible approaches to their correction.

### 1) Constant Returns to Scale

Obviously if there are increasing (or decreasing) returns to scale, output elasticities with respect to factor inputs cannot be directly inferred from factor shares in cost. If one proceeds to apply equation (3) anyway, output growth due to scale economy exploitation will be misattributed to factor productivity growth. Specifically, combining (2) and (3), the discrepancy between  $\hat{\epsilon}_{Y,t}$  and  $\epsilon_{Y,t}$  can be expressed as a function of growth in the factor inputs:

$$(4) \quad \hat{\epsilon}_{Y,t} = \epsilon_{Y,t} + \sum_{j=1}^k (\theta_j - s_j) (\dot{v}_j / v_j)$$



Hence, for example, if all factors grow at the same rate,  $g$ , TFP growth will be overstated by the procyclical amount  $g(\sum \theta_j - 1)$ . This is not so horrible if one does not care to isolate scale effects from technical innovation and other unobservable forces, but the figures can be misleading, particularly if they are used to study the temporal correlation of TFP growth with other cyclical variables, as in Table 1 and many earlier studies.

It is possible to isolate true TFP growth, given knowledge of the returns to scale. Clearly, if the individual output elasticities,  $\theta_j$ , are known, equation 2 can be used directly to calculate  $\epsilon_{Y,t}$ . Alternatively, if only the returns to scale are known, one may use a dual approach to obtain productivity measures from the cost function. Let the cost function  $C = g(w, Y, t)$  be the dual to equation (1), where  $w$  is the vector of input prices. Then TFP growth can be written as (Otha, 1975; Morrison, 1989):

$$(5) \quad -\epsilon_{Y,t} = \epsilon_{C,t} / \epsilon_{C,Y} \\ = (\dot{C}/C - \epsilon_{C,Y}(\dot{Y}/Y) - \sum_{j=1}^k (w_j v_j / C)(\dot{w}_j / w_j)) / \epsilon_{C,Y}$$

Here  $\epsilon_{C,Y}$  is the elasticity of cost with respect to output, so values less than one reflect increasing returns to scale. (Notice that under constant returns this expression implies that TFP can be calculated as the growth in share-weighted input prices, less growth in cost per unit output.)

Regardless of whether one uses a cost function or a production function, some unobservable parameters are involved in the calculations. This problem can be solved by going to an econometric model if sufficient observations are

available. For example, the cost function  $g(w, Y, t)$  can be estimated to obtain  $\epsilon_{c,y}$ .<sup>10</sup> Similarly, one may be able to obtain  $\theta_j$  values by estimating equation (1) directly. Simultaneity is a potential problem with this approach, but it should not be assumed that Tornqvist indices based on equation 3 avoid the issue. Such indices divert attention from causality because there are no degrees of freedom, so we tend not to think in terms of behavioral relationships and population disturbances.<sup>11</sup>

Although there are some exceptions, data limitations often make the econometric approach to handling scale economies infeasible at the sectoral or macro level in LDCs. Nonetheless, it is the natural framework in which to organize one's thoughts about behavior, technology and measurement error, all of which should be considered when interpreting non-econometric TFP figures. Sensitivity analysis motivated by this type of reflection should help the analyst decide how seriously to take his or her calculated figures.<sup>12</sup>

Finally, as noted by Chavas and Cox (1990), it is possible to use programming-based approaches to productivity measurement that do not rely on

---

<sup>10</sup> Recent examples of cost function estimation based on sector-level data include Kwon (1985) for Korea, Morrison (1989) for the U. S., and Fuss and Waverman (1986) comparing Canada and the U. S.

<sup>11</sup> Using a given data base, results from econometric estimation do not always conform to those from residual-based calculations, nor do figures based on cost functions necessarily square with those based on production functions. Quite aside from scale economies there are several reasons why this might occur. First, as Diamond *et al* (1978) have demonstrated, "a set of production data can be generated by more than one combination of technology and technical change . . ." Second, the exogeneity assumptions implicit in the different specifications are typically at odds with one another.

<sup>12</sup> A good example of sensitivity analysis in this spirit is Slade (1986), who also considers the problem of short-run fluctuations in capacity utilization (to be discussed below).

constant returns. Suppose technology may be characterized at time  $t$  by some  $K+1 \times 1$  vector  $A_t = (A_0, A_1, \dots, A_K)$ , where  $A_0$  reflects the level of Hicks neutral productivity, and  $A_i$  represents the effectiveness of the  $i^{\text{th}}$  input. Then the production function (1) becomes  $Y_t = f(v_t, A_t)$  and the dual cost function becomes  $C_t = g(w_t, Y_t, A_t)$ . If changes in  $A_0$  can be viewed as additive shifts to output, and changes in the other  $A_i$  can be viewed as additive shifts in the associated effective input stocks, a number of conditions that are necessary for cost minimizing behavior can be derived. Exploiting these conditions, linear programming techniques can be used to impute factor-augmenting and disembodied technical changes without assuming constant returns to scale. (Tests of the constant returns to scale hypothesis itself can also be constructed.) For example, for any two points in time,  $t$  and  $s$ , the following inequalities must hold for some non-negative  $\lambda_t$ :

$$\lambda_t(Y_t - A_{0t} - Y_s + A_{0s}) + \sum_{j=1}^K w_{jt}(v_{js} + A_{js} - v_{jt} - A_{jt}) \geq 0$$

When enough pairs of years are available to overidentify the trajectory of the vector  $A$ , goodness of fit measures based on slack variables can be introduced.

This framework has two obviously appealing features: it doesn't place many restrictions on the form of the production function, and it can be implemented with readily available series on output, inputs, and factor prices. However, offsetting these virtues are the assumption of continuous long run equilibrium and the lack of a framework for statistical inferences. I am unaware of applications to developing countries yet, and I would be curious to see whether such exercises yield sensible figures. (If sufficient time series are available, the problem of short-run disequilibria could be lessened by only using peak years of the business cycle.)

## 2) All factors are freely adjusted

If adjustment costs are associated with changes in the stock of capital -- as surely they must be -- then short run fluctuations in output are likely to be accomplished mainly through adjustments in labor and intermediate inputs. Equation 3 is no longer a valid restatement of 2, and the appearance of procyclical bursts of productivity growth is created. No one disputes this point, although many have ignored it.

When installed capital is characterized by a fixed-coefficient technology, the reason this happens is obvious: capital in service fluctuates with the business cycle, but measured capital does not. The same procyclical bias arises with neoclassical technologies, although the logic is less direct. Suppose that we augment our production function (1) to include quasi-fixed factors ( $v_j$ ,  $j=k+1, m$ ). Then the equality  $w_j = P\partial f/\partial v_j$  will not necessarily hold in the short run for  $j > k$  because when choosing these factors, firms optimize by weighing adjustment costs against operating profits. Growth in the quasi-fixed factors will be dampened during periods of expanding demand, so the value of the marginal product of these factors will exceed their market prices:  $\theta_j - s_j > 0$ . Accordingly, application of equation 3 results in an estimated productivity residual that tends to be too high when the economy is growing out of recession:

$$(6) \quad \hat{\epsilon}_{Y,t} = \epsilon_{Y,t} + \sum_{j=k+1}^m (\theta_j - s_j) (\dot{v}_j / v_j)$$

The opposite occurs going into recession, but unless adjustment costs are independent of the direction of factor stock changes (an unlikely condition),

the bias will not be of equal magnitude and averages of annual productivity production figures will be biased as well. This measurement problem looks like a special case of equation 4 because adjustment costs cause short run deviations from CRS. It is, of course, another explanation for the strong correlation between output growth and productivity growth found in Table 1.

Two approaches to dealing with this problem have been around for some time. The first is to base growth calculations on adjacent business cycle peaks, under the assumption that full capacity utilization characterizes these years. Although this approach may not be feasible when time series are short or when a particular subperiod is of interest, it has much to recommend it.<sup>13</sup>

The second "old" approach is to weight capital stock figures by some measure of capacity utilization (e.g., Jorgenson and Griliches, 1967). These capacity adjustments cannot be reconciled with production technologies that assume smooth substitution between labor and capital. The reason is apparent from equation 6, which implies that the weight on capital growth is the source of the distortion rather than the growth rate of capital itself (e.g., Berndt and Fuss, 1986). Nonetheless, capacity adjustments can be justified under the assumption of fixed coefficient technologies for installed capacity, because the portion of the capital stock involved in production then fluctuates directly with output. To the extent that there are less substitution possibilities in developing countries -- e.g., because higher uncertainty

---

<sup>13</sup> Jorgenson et al (1987) provide a recent example of the peak-to-peak approach.

makes managers choose technologies with flat average cost schedules -- the capacity adjustment approach may be well suited there.<sup>14</sup>

An alternative approach to dealing with the capacity utilization problem has emerged in the past decade.<sup>15</sup> It amounts to imputing the true marginal product (or "shadow price") of capital under the maintained hypothesis that installed capacity and labor are combined in a neoclassical production function. Of course, given this true shadow price, the appropriate weight can be used on capital growth in equation (2). Hulten (1986) suggests a simple approach for the case of CRS and one quasi-fixed factor. Under these conditions, output elasticities with respect to factors sum to 1, so equation 2 generalizes to include the quasi-fixed ( $k+1^{st}$ ) factor as follows:

$$(7) \quad \epsilon_{Y,t} = \dot{Y}/Y - \sum_{j=1}^k \theta_j (\dot{v}_j/v_j) - [1 - \sum_{j=1}^k \theta_j] (\dot{v}_{k+1}/v_{k+1})$$

All of the variable factors are paid their marginal product, so in the absence of other complications, it is legitimate to use  $s_j = \theta_j$  to render the right-hand side of (7) observable. Conveniently, this is what many students of LDCs have been doing anyway, given the lack of reliable data on the rental price of capital. (Table 1 figures are calculated in this way.) Unfortunately, as we have seen, a strong procyclic pattern is still found in TFP growth rates, suggesting that other measurement problems remain.

---

<sup>14</sup> Kim and Kwon (1977) and Kwon (1986) provide examples of capacity adjustments in studies in developing countries. Notably, after making their adjustments they conclude that a significant portion of measured TFP growth is illusory.

<sup>15</sup> A symposium devoted to this approach appeared in volume 33 of the Journal of Econometrics.

Alternatives to Hulten's procedure for calculating the shadow price of capital are more involved, and are less likely to be useful for analysis in LDCs. Berndt and Fuss (1986) suggest altering the weight on capital in equation (3) using Tobin's  $q$  or ex post internal rates of return, while Morrison (1986) estimates the production technology in an econometric model of producer behavior with adjustment costs and uncertainty. This latter approach is perhaps the most satisfying from a theoretical perspective but it requires many maintained hypotheses and excellent data.

### 3) Competitive Behavior

The equivalence between equations (1) and (2) also breaks down if producers enjoy some monopoly power. Then revenues will not match the opportunity costs of factors of production, and again, factor shares are inappropriate weights. Recently Robert Hall and others have stressed this point, and proposed a methodology for extracting "true" productivity growth figures from observed series, generating a measure of price-cost mark-ups along the way.<sup>16</sup> The logic is essentially the following.

Suppose that the representative plant faces a downward sloping demand curve,  $P = p(Y)$ .<sup>17</sup> Then the first-order conditions for profit maximization are:

---

<sup>16</sup> Hall (1986, 1988), Domowitz, Hubbard and Petersen (1988), Shapiro (1987), Caballero and Lyons (1989a, 1989b, 1990).

<sup>17</sup> Here I am glossing over the distinction between plant-level output and industry-wide output. One way to be strictly correct is to assume Cournot behavior and write the market price as a function of each individual plant's output. The relevant elasticity of demand is with respect to adjustment in a single plant's output, holding all others constant. These observations should make it clear that we are justified in applying this framework at the sectoral level only when all firms are identical.

$$(8) \quad w_j = P[1 + \mu] \partial f / \partial v_j, \quad j = 1, \dots, k,$$

where  $\mu$  is the inverse of the elasticity of demand perceived by the representative plant, and  $1/[1+\mu]$  is its mark-up of price over marginal cost. Given that  $\mu$  is negative, factor shares understate the true marginal product of the associated factors, so TFP calculations based on equation (2) yield:

$$(9) \quad \begin{aligned} \hat{\epsilon}_{y,t} &= \dot{Y}/Y - (1+\mu) \sum_{j=1}^k \theta_j (\dot{v}_j/v_j) \\ &= \epsilon_{y,t} - \mu \sum_{j=1}^k \theta_j (\dot{v}_j/v_j) \end{aligned}$$

Accordingly, the extent of the upward bias depends directly upon the rate of growth in factor stocks, and measured productivity growth is once again procyclical.

Assuming constant returns and two factors, Hall suggests the problem can be corrected without knowing  $\mu$  by regressing growth in output per unit capital on the product of labor's share and growth in labor per unit capital ( $v_1/v_2$ ):

$$(10) \quad (\dot{Y}/Y - \dot{v}_2/v_2) = \beta_0 + \beta_1 s_1 (\dot{v}_1/v_1 - \dot{v}_2/v_2) + u$$

When firms have market power,  $\mu < 0$  and  $s_1 = \theta_1(1+\mu)$ . Accordingly, equation (10) is a restatement of (2) with  $\beta_1 = 1/(1+\mu)$  and  $\beta_0 = \epsilon_{y,t} - u$ . This means that successful estimation of the parameters of equation (10) should not only yield a consistent estimate of the true mean rate of TFP growth,  $\hat{\beta}_0$ , it should



also provide a consistent estimate of the mark-up over marginal cost,  $\hat{\beta}_1$ .<sup>18</sup> Finally, fluctuations around the mean rate of TFP growth are represented by  $u$ , so residuals from the regression should indicate the relative magnitudes of permanent and transitory productivity growth, corrected for non-competitive pricing.

The Hall methodology is appealing, but for several reasons its validity hinges critically on the availability of good instrumental variables. First, although mark-ups are treated as parametric in equation (8), they are likely to be procyclical (e.g., Domowitz, et al, 1986). This implies that equation (10) is really a random coefficient model with  $\beta_1 = \beta_1^0 + \epsilon$ , where  $\epsilon$  is a cyclical disturbance. Viewed this way, the disturbance of the estimated equation is actually  $u + \epsilon s_1(\dot{v}_1/v_1 - \dot{v}_2/v_2)$ , and to the extent that factor stock growth is itself procyclical, OLS will yield estimated  $\beta_1$  values that are biased upward. Second, even if mark-ups do not vary with the business cycle, an analogous bias in OLS estimates will be present whenever the transitory component of true TFP growth ( $u$ ) is correlated with factor stock growth. Hall recognises the potential correlation of factor stocks with the disturbance term, and uses GNP growth as an instrument when estimating equation (10). But critics of the Hall methodology argue that the problem remains, given that GNP growth is itself likely to be correlated with  $u$  and  $\epsilon$ . In support of this view, Abbott et al (1989) note that Hall's instrumental

---

<sup>18</sup> One detail should be noted here. If the production technology expresses value-added as a function of primary factors,  $\beta_1$  measures the markup of value-added prices over marginal primary factor costs. Hall (1986) presents the calculation necessary to retrieve mark-ups of gross output prices over marginal cost:  $\beta_1^* = \beta_1/[1+(\beta_1-1)m]$ , where  $m$  is the fixed ratio of materials cost to total revenue.

variable (IV) estimates generally produce higher  $\beta_1$  values than OLS estimates, suggesting that any upward bias is actually exacerbated by the IV approach.

Leaving aside the issue of instruments, how sensitive is the Hall methodology to violations of the assumptions needed for standard TFP calculations? First, we have already noted that if there are adjustment costs, under constant returns to scale the marginal product of capital is one minus labor's share. This assumption is built into equation (9), so adjustment costs in themselves may not create problems. Second, we have seen that increasing returns mean that capital's marginal product cannot be calculated as one minus labor share. But since we have adopted a parametric framework this need not create problems either. The appropriate equation to estimate becomes:

$$(11) \quad \dot{Y}/Y = \beta_0 + \beta_1 s_1(\dot{v}_1/v_1 - \dot{v}_2/v_2) + \beta_2 (\dot{v}_2/v_2) + u,$$

where  $\beta_2$  measures returns to scale (e.g., Hall, 1988b).<sup>19</sup> Third, although the Hall methodology is designed to deal with product market imperfections, it presumes competitive factor markets. If the first order conditions in equation (8) fail to hold because of monopsony power, then estimates of  $\beta_1$  will reflect this distortion as well as mark-up pricing. Moreover, given that different distortions will characterize different factor markets, equation (10) will generally be a misspecification: each component of factor growth should enter separately. (Even if this modification is made, it becomes difficult to interpret coefficients other than  $\beta_0$ .) Finally, if there is

---

<sup>19</sup> Interestingly, Griliches and Mairesse (1983) estimated equations like this before the Hall methodology had been introduced, but did not interpret their findings to imply non-competitive behavior.

plant heterogeneity, it will generally be inappropriate to fit either (9) or (10) on a sector-wide basis. Nonetheless, in plant-level panels, certain types of cross-plant differences (e.g., in mark-ups or productivity growth) can be controlled for (Abbott, Griliches and Hausman, 1989; Harrison, 1989).

Each country author in the ICPT project was asked to estimate a three-factor version of equation 11, both with OLS and using instruments.<sup>20</sup> In two of the studies (Turkey and Cote d'Ivoire), the authors investigate whether trade reforms were associated with a change in either the corrected TFP growth rate or the price-cost mark-up. They do this by including a dummy (D) that takes a value of one in sample years when the economy is under a "liberal" trade regime, and zero otherwise. Their estimated equation is:

$$\dot{Y}/Y = \beta_0 + \beta_1 \sum_{j=1}^3 s_j (\dot{v}_j/v_j) + \beta_2 (\dot{v}_3/v_3) + \beta_3 D + \beta_4 D \sum_{j=1}^3 s_j (\dot{v}_j/v_j) + u,$$

where  $v_1$  is labor,  $v_2$  is materials,  $v_3$  is capital, and the coefficient  $\beta_2$  now reflects deviations from constant returns to scale. The results are reported in Table 2 for regressions that pool observations across industries.

(Industry by industry regressions are also available for most of the studies summarized here, but the pooled results appear to reasonably summarize the more detailed findings.)

---

<sup>20</sup> The instruments were values of factor prices, output, and input growth. The three factors were labor, intermediates, and capital. Indtermediates goods were not available in the Moroccan data base, so it was not possible to construct a comparable Tornqvist index of total factor stock growth. Equation 11 was fit using value added instead, the results are not comparable to those based on gross output, and so are not reported in table 2. (Refer to footnote 18 for details.)

Table 2: Separating "True" TFP Growth and Price-Cost Mark-ups\*

$$\dot{Y}/Y = \beta_0 + \beta_1 \sum_{j=1}^3 s_j (\dot{v}_j/v_j) + \beta_2 (\dot{v}_3/v_3) + \beta_3 D + \beta_4 D \sum_{j=1}^3 s_j (\dot{v}_j/v_j) + u$$

	<u>Chile</u>		<u>Colombia</u>		<u>Turkey</u>		<u>Cote d'Ivoire</u>	
	<u>OLS</u>		<u>OLS</u>	<u>IV</u>	<u>OLS</u>	<u>IV</u>	<u>OLS</u>	<u>IV</u>
corrected TFP growth $\beta_0$	-.104 (.065)		.018 (.029)	.023 (.033)	-.042 (.053)	-.07 (.08)	n.a.	n.a.
mark-up $\beta_1$	.817* (.071)		1.07* (.066)	1.31* (.200)	1.04* (.089)	1.67* (.81)	1.08* (.014)	1.24* (.204)
excess over CRTS $\beta_2$	.136 (.081)		-.204* (.049)	-.412* (.119)	.131 (.128)	1.51 (1.0)	--	--
lib. TFP growth shift $\beta_3$		--	--		.045 (.156)	.05 (.05)	.01 (.01)	n.a.
lib. mark-up shift $\beta_4$		--	--		.065* (.021)	-.11 (1.3)	-.02 (.03)	-.305 (.232)
$\bar{R}^2$	.693		.622			.187	.88	
F	13.51		14.18			3.05		
obs.	189		270			260	1944	
d.f.	154		241			230		

\* 3-digit industry dummies were included in the Chile, Colombia, and Turkey regressions but are not reported here. The Cote d'Ivoire regressions are based on plant-level data; all others are based on three-digit industry level data. All estimates except those for the Cote d'Ivoire are preliminary.

First notice that the mark-up coefficients look sensible in most cases, although they are suspiciously low in Chile. This could reflect reality -- Chile underwent a major recession during the sample period, with unemployment rates approaching thirty percent. It is also generally believed to be the country with the most competitive economic environment. On the other hand, it is hard to imagine that firms priced at eighty two percent of factor cost on average during the period 1979-86. Instrumenting the factor stock growth variable usually increases the mark-up coefficient, so if IV results were available for Chile the results might conform better to priors.

It is also worth noting that one can typically reject the null hypothesis that each share-weighted factor stock growth rate has the same coefficient. (Tests not reported here.) Hence the estimated model is a misspecification, probably because of factor stock mismeasurement and/or factor market imperfections. One likely problem is that capital is not homogeneous, and stocks recently installed do not reach their full productivity for some time.<sup>21</sup> Hence the current change in capital stocks is unlikely to accurately reflect the increment to capital services, and the appearance of decreasing returns to scale is often created.

The studies that allowed mark-ups and TFP growth rates to shift with trade liberalization both found that the latter tended to rise, but insignificantly so. Taking the IV estimates as the most reliable, one finds that mark-ups also fell by an insignificant amount in both cases. More detail on these findings and on estimation issues may be found in Harrison (1990), who exploits her plant-level approach to control for a number of complicating

---

<sup>21</sup> For convincing evidence on this point, see Pakes and Griliches (1984).

factors. She concludes that certain protected sectors had significant mark-ups, and that these mark-ups fell with trade liberalization and exchange rate appreciation. Also, although TFP measures based on equation (3) correlate strongly with trade regimes, the corrected TFP measure based on equation (10) (i.e.,  $\hat{\beta}_0$ ) does not. Finally, the type of instruments used appears to matter a good deal.

Overall, the Hall methodology appears to hold some promise, although it has several potentially serious shortcomings. First, attributes all deviations of factor shares from marginal productivities to product market distortions. Second, it is disturbingly sensitive to choice of instruments. Finally, it fails to deal with a number of the same problems that limit the usefulness of Tornqvist indices. Particularly when applied at the sector level, it involves heroic assumptions about the uniformity of technologies and behavior across plants, and the comparability of factor inputs, both across plants and through time. This brings us to the next basic issue I wish to focus on: plant heterogeneity.

#### IV. MICRO APPROACHES TO PRODUCTIVITY MEASUREMENT

Even if the problems of scale economies, quasi-fixed factors, and non-competitive pricing are successfully dealt with, some potentially troublesome problems remain with the residual-based calculations of productivity growth. These have to do with the underlying presumption that a well defined production technology describes all plants within the industry, sector, or country of analysis. If technological innovation takes place through a gradual process of efficient plants displacing inefficient ones, and/or through the diffusion of new knowledge, the approaches to productivity

measurement based on "representative plant" behavior are at best misleading. At worst, they fail to capture what is important about productivity growth altogether, as Nelson (e.g., 1981) has long argued.

#### A. Heterogeneity and Productivity Growth: An Overview

One of the most obvious features of industrial censuses is the tremendous amount of cross-plant heterogeneity. Even within narrowly defined industries, one observes wide ranges of output levels, capital-labor ratios, capital stock vintage, and profitability (e.g., Berry, 1989; Tybout, et al, 1990). Accordingly, if changes in productivity are systematically induced by changes in the cross-plant distribution of these features, the productivity growth process will not be revealed by sectoral or macro analysis. An important question, about which we know very little, is whether such changes in the distribution of plants account for associated sectoral changes in output per unit input.

A complete analysis of this issue would require massive engineering studies, and is well beyond the scope of this paper.<sup>22</sup> Nonetheless, to provide a modest start, we can construct some simple summary statistics that reveal something about the role of plant turnover, scale, and heterogeneity in shaping productivity growth.<sup>23</sup> Specifically, for a given industrial sector, let  $F = h(v)$  be a scalar index of factor input use. (For example,  $F$  might

---

<sup>22</sup> Pack (1989) surveys the literature on engineering studies of certain groups of plants. He finds that "the emphasis in the recent technical change studies on the firm rather than the industry makes it difficult to evaluate the significance of the reported innovative activity. . . . [A]lmost all of the technical change studies examine the history of only one or two firms."

<sup>23</sup> The remainder of this section is based upon Roberts and Tybout (1990b)

simply be number of workers, or it might be a share-weighted aggregation over capital, labor and intermediates.<sup>24</sup>) Then total industrial output (Y) can be expressed as output per unit factor input ( $y = Y/F$ ) times number of plants (N), times factor input per plant ( $f = F/N$ ). In discrete growth terms:

$$(11) \quad \Delta Y/Y_{t-1} = (\Delta y/y_{t-1})(\omega_1) + (\Delta f/f_{t-1})(\omega_2) + (\Delta N/N_{t-1})(\omega_3),$$

$$\text{or } G = G_1 + G_2 + G_3$$

The first right-hand-side term reflects productivity growth, the second term reflects changes in the average scale of operations (now measured by factor use), and the third term reflects net entry. Weights  $\omega_1$ ,  $\omega_2$ , and  $\omega_3$  are there simply because the equation is in discrete terms; each will be close to one.<sup>25</sup> This identity reveals not only whether output expansion has come mainly from productivity growth, but also whether productivity changes have been accompanied by changes in scale and/or net entry.

For three of the countries involved in the ICPT project we obtained annual data on all plants with at least 10 workers. Identification codes allowed us to track these plants through time, so it was possible to monitor entry and exit into the data base. (Ideally these would reflect the births and deaths of plants, but in practice they also reflect crossings of the 10

---

<sup>24</sup> One appealing possibility would be to base the weights on real shadow prices, making the ratio  $Y/F$  the inverse of domestic resource cost (DRC).

<sup>25</sup> The weights are averages of all possible variants of the identity. Specifically,  $\omega_1 = \overline{fNy}_{t-1}/Q_{t-1}$ ,  $\omega_2 = \overline{yNf}_{t-1}/Q_{t-1}$ , and  $\omega_3 = \overline{fyN}_{t-1}/Q_{t-1}$ , where

$$\overline{ab} = (1/6)[2a_t b_t + 2a_{t-1} b_{t-1} + a_t b_{t-1} + b_t a_{t-1}].$$



worker threshold.) Letting  $F$  be number of workers so that  $G_1$  measures growth in labor productivity, implementation of the identity (11) resulted in the figures reported in table 3.<sup>26</sup> Here, in addition to figures for the manufacturing sector overall, we sort plants into three broad subgroups: exportable producers, importable producers, and nontradeable producers.<sup>27</sup> Year-to-year fluctuations in our decomposition probably largely reflect capacity utilization effects. Hence to get an overview of the long-run significance of each effect, we begin with an intertemporal average of each component value for each country.

---

<sup>26</sup> We did not observe capital stock figures for all plants, so it was not possible to construct broader indices of factor use.

<sup>27</sup> A firm is classified as producing an exportable product if its three-digit industry exports more than 25 percent of its output, on average. A firm is classified as producing an importable product if its three-digit industry exports less than 25 percent of its output, but at least 25 percent of the domestic market for this industry's good is supplied by imports. All other firms are classified as nontradeable producers.

**Table 3: Output Growth Decomposition for Chile, Colombia, and Morocco  
(Cross-Year Averages)**

	Growth in:			
	Output (G)	Productivity (G <sub>1</sub> )	Scale (G <sub>2</sub> )	No. Plants (G <sub>3</sub> )
<b>Chile (1979-85)</b>				
all plants	.014	.044	.018	-.049
exportables	.085	.093	.034	-.042
importables	.001	.036	.014	-.049
nontraded	-.018	.013	.016	-.047
<b>Colombia (1977-87)</b>				
all plants	.040	.048	.004	-.002
exportables	.079	.037	.009	.033
importables	.053	.061	.000	-.008
nontraded	.043	.041	.004	-.002
<b>Morocco (1984-87)</b>				
all plants	.046	-.038	.009	.075
exportables	.026	-.105	.042	.089
importables	.083	-.001	.013	.071
nontraded	.039	.018	-.038	.059

source: Roberts and Tybout (1990b)

There are two striking features of table 3. The first is that entry and exit are quite significant, implying that there are high returns to improving our understanding of turnover processes. The second is that output expansion appears to occur through very different mechanisms in the different economies, even though the reported statistics are averages spanning at least four years. For example, in Chile and Morocco adjustment comes largely from entry and exit, while in Colombia adjustments in the scale of incumbent plants appears more important. Sector-specific differences in the nature of adjustment are also apparent: tradeables appear to accomplish more adjustment through entry and exit than non-tradeables in two of the three countries. (Contrast, for example, the average growth in scale among exportables versus nontradeables in Morocco.) Without getting into the details of each country's policies and macro conditions, we note that these results suggest that hysteresis-type models of behavior hold promise. Further work characterizing the degree of uncertainty in these countries should help establish a policy link between the dimensions in which adjustment take place and the prevailing trade regime, inter alia.<sup>28</sup>

Table 3 obscures the fact that entering, exiting and incumbent plants probably differ systematically in terms of size and productivity. Documenting these differences should help us to understand the influence of plant heterogeneity on measured TFP. To this end we further decompose each right-hand-side element of equation 11. First, we write our productivity growth index,  $G_1$ , as reflecting three influences:

---

<sup>28</sup> I am currently pursuing this line of research with Mark Roberts. Conceptually, the econometric literature on state dependence provides a convenient point of departure.

$$(12) \quad \Delta y/y = \Delta y_c \bar{\alpha}_c/y + \Delta \alpha_c [\bar{y}_c^{-1} (y_d + y_b)]/y + (y_b - y_d)(1 - \bar{\alpha}_c)/y$$

$$G_1/\omega_1 = G_{11}/\omega_1 + G_{12}/\omega_1 + G_{13}/\omega_1$$

Here  $\alpha_c$  is the proportion of total factor use accounted for by plants which were in the industry both last period and this period (hereafter "continuing" or "incumbent" plants), and  $y_c$  is average productivity among these plants. (A bar above a variable indicates an average of last period's and this period's value.) Similarly,  $y_b$  is productivity among plants that have entered the industry this period, and  $y_d$  is productivity among plants that were in the industry last period, but exited this period. Hence the first term ( $G_{11}$ ) indicates what portion of productivity growth is due to productivity improvements among incumbents, the second term ( $G_{12}$ ) indicates how changes in the market share of incumbent plants influence productivity (hereafter, the "net entry effect"), and the last term ( $G_{13}$ ) reflects any improvement in productivity due to the replacement of exiting plants with entering plants (hereafter the "turnover effect").

If entering plants are more productive than exiting plants,  $G_{13}$  will be positive, reflecting desirable turnover effects. On the other hand, increases in the net entry rate cause the share of employment among incumbent plants to fall ( $\Delta \alpha_c < 0$ ), so if productivity is higher among incumbents than the average productivity among entering and exiting plants, overall productivity growth may be dampened by increases in entry.

Next consider growth in scale,  $G_2$ . If we define  $\lambda_c = N^c/N$  as the number of incumbent plants divided by the total number of plants, this term can be similarly decomposed:

$$(13) \quad \Delta f/f = \Delta f_c \bar{\lambda}_c/f + \Delta \lambda_c [\bar{f}_c - \frac{1}{2}(f_d + f_b)]/f + (f_b - f_d)(1 - \bar{\lambda}_c)/f,$$

$$\text{or} \quad G_2/\omega_2 = G_{21}/\omega_2 + G_{22}/\omega_2 + G_{23}/\omega_2$$

Here  $G_{21}$  reflects expansion in plant size (i.e., factor use) among incumbents, weighted by incumbents' market share, and  $G_{22}$  and  $G_{23}$  tell us about the relative size of incumbents, entrants and exiting plants. The former is the gap between incumbent size and the average size among entering and dying plants, all weighted by the change in incumbent share. The latter the differential in size between entering and dying plants, weighted by the share of non-incumbents.

The last term in equation 1 ( $G_3$ ) represents the effect of net entry on expansion; it too can be further decomposed:

$$(14) \quad \Delta N/N = N^b/N - N^d/N, \text{ or}$$

$$G_3/\omega_3 = G_{31}/\omega_3 - G_{32}/\omega_3.$$

This is, of course, the difference between entry and exit rates. Values of the right-hand side elements of equations (12), (13), and (14) are presented in Table 4. Again, to approximate long-run values, these are averages over annual growth rates.

Table 4: Detailed Growth Decomposition for Chile, Colombia, and Morocco  
(Cross-Year Averages)

	Growth in:								
	Productivity			Scale			No. Plants		
	incum- bents <u>G<sub>11</sub></u>	net entry <u>G<sub>12</sub></u>	turn- over <u>G<sub>13</sub></u>	incum- bents <u>G<sub>21</sub></u>	net entry <u>G<sub>22</sub></u>	turn- over <u>G<sub>23</sub></u>	gross entry <u>G<sub>31</sub></u>	gross exit <u>G<sub>32</sub></u>	
<b>Chile</b> <b>(1979-85)</b>									
all plants	.030	.012	.002	-.006	.018	.006	.062	.111	
exportables	.078	-.002	.016	-.003	.008	.029	.125	.167	
importables	.030	.001	.006	-.002	.014	.003	.073	.123	
nontraded	-.001	.011	.002	-.009	.016	.009	.065	.112	
<b>Colombia</b> <b>(1977-87)</b>									
all plants	.040	.003	.004	-.002	.004	.000	.160	.162	
exportables	.033	-.002	.004	-.001	.004	.005	.173	.182	
importables	.044	.007	.009	-.004	.002	-.000	.178	.186	
nontraded	.040	.002	-.001	-.001	.007	-.002	.137	.143	
<b>Morocco</b> <b>(1984-87)</b>									
all plants	-.021	-.017	.001	.041	-.039	.007	.135	.060	
exportables	-.072	-.031	-.001	.058	-.039	.022	.181	.093	
importables	-.010	-.006	.015	.051	-.016	-.022	.171	.100	
nontraded	.028	-.013	.002	.004	-.028	-.014	.155	.086	

source: Roberts and Tybout (1990b)

Table 4 reveals several interesting patterns. First, the overall significance of plant turnover in determining growth rates can be crudely gauged by comparing total growth ( $G$ ) from table 3 with growth due to incumbents ( $G_{11} + G_{21}$ ) from table 4. For example, output grew by an annual average of 1.4 percent in the Chilean manufacturing sector; while if there had been no entry or exit, it would have grown by  $.030 - .006 = .024$ . Put differently, net exit cut output growth almost in half. Similarly, net entry increased the average annual Moroccan growth rate from 2 percent to 4.6 percent.

These figures suggest that entering and exiting plants play a significant role in the evolution of industry. However, if these plants' technologies are identical to those of incumbents, this finding need not invalidate sectoral level productivity analysis. Do the data suggest technology differences? Consider the labor productivity components,  $G_{12}$ , and  $G_{13}$ . If the former is non-zero, it must be that incumbents have average productivity levels that differ from the average among entering and exiting plants. Also, if the latter is non-zero, it must be that exiting plants have productivity levels that differ from entering plants. Both appear to be the case. In Chile and Colombia, net exit increases the market share of incumbents, and this improves productivity. Indeed, among Chilean importables and nontradeables, this is the main source of productivity change (compare  $G_{12}$  and  $G_1$ ). Net entry does the opposite in Morocco.

Differences in productivity between entering and exiting plants generally have smaller effects on sectoral aggregates (compare  $G_{13}$  and  $G_1$ ), but they are by no means negligible. As one would hope, exiting plants tend

to be less productive than the entering plants that displace them.<sup>29</sup> Of course, part of the productivity difference between incumbent plants and others is due to the fact that the former are relatively large, and more capital intensive. (This in itself is an argument against sector-level analysis.)

Is scale heterogeneity also significant? It would appear so. Incumbents are much larger than either entering or exiting plants (e.g., Roberts, 1989; Tybout, 1989), so the net exit that takes place in Chile significantly increases average plant size ( $G_{22}$ ), even though incumbent plants are shrinking. The same logic works in reverse for Morocco, when rapid net entry takes place. This finding means that, to the extent that scale economies matter, the pro-cyclical tendencies of factor productivity are likely to be dampened by turnover. (Whether the infusion of new plants eventually leads to high productivity as learning by doing takes place is an open issue.<sup>30</sup>) It also means that estimates of production or cost functions based on sectoral level data are suspect.

Finally, with respect to gross entry and exit rates, it is surprising that all three countries register figures that match or exceed those found in the U.S. Hence the popular view that institutional barriers to entry and exit are relatively important in developing countries is not borne out by these

---

<sup>29</sup> Work in progress based on cohort-specific production and cost functions confirms that exiting plants are less productive than entering plants in both Colombia and Chile.

<sup>30</sup> In principle, this question can be directly addressed by fitting cohort-specific cost or production functions. Some researchers on the ICPT project are currently attempting this.



data.<sup>31</sup> Moreover, plants that enter and exit in these countries are as large relative to the industry-wide average plant size as they are in the United States.

#### B. Trade, Entry and Exit

All of the above points in the direction of micro approaches to productivity growth based on changing distributions of heterogeneous plants. An emerging analytical literature provides some theoretical underpinnings (Jovanovic, 1982; Pakes and Ericson, 1987; Jovanovic and Lach, 1989; Lambson, 1988), but the models are as yet too abstract to lend themselves to empirical implementation.<sup>32</sup> This literature does suggest that we might improve our understanding of growth processes by devoting more empirical attention to (1) the entry, exit and growth processes, (2) cohort-specific cost or production functions, and (3) learning curves. Knowledge of the first variety will help us understand the composition of an industry at each point in time, while knowledge of the latter two varieties will help us map alternative compositions into associated sector-wide productivity levels. The functions representing entry, exit, growth, and production or cost should be time-dependent and potentially sensitive to regime changes. This subsection is a selective review of what we know about each of these and their relation to trade policy.

---

<sup>31</sup> This is not immediately apparent from Table 4. It can be inferred by comparing the five-year entry/exit patterns reported in Dunne, Roberts and Samuelson (1988) with cohort survival figures reported in Roberts (1989), Tybout (1989), and Haddad et al (1990).

<sup>32</sup> See, however, Erikson and Pakes (1987) and Dunne, Roberts and Samuelson (1989) for some non-parametric tests of their implications.

Several stylized facts concerning growth, entry and exit are well established. Specifically, as new plants mature, their probability of failure drops, and their size increases toward industry norms.<sup>33</sup> However, there is relatively little in the literature documenting the effects of trade policy on these processes. To generate some preliminary results on this issue, regressions linking entry and exit with industrial output growth and import penetration rates were attempted for several of the ICPT project countries (Tybout, 1989; Roberts, 1989). These regressions were done using annual data on three-digit industries, controlling for fixed industry effects and time effects with dummies. Hence the coefficients on import penetration rates were identified with temporal fluctuations, not cross-industry contrasts.

Several findings are worth mentioning. First, output growth is positively correlated with entry, but does not correlate significantly with exit. The latter depends heavily on time dummies, suggesting that macro phenomena like high interest rates are more important than product market fluctuations in causing failures. Second, controlling for fixed industry effects, macro conditions, and output growth, fluctuations in import penetration do not correlate significantly with entry and exit patterns. This could mean that our regression model fails to capture the relevant dynamics, or it could mean that all significant effects of import penetration are picked up through industry-wide fixed effects and output fluctuations. Third, industry dummies (not reported) are generally significant, so to the extent that liberalization changes patterns of specialization, it is likely to change

---

<sup>33</sup> For recent studies of the U.S. see Dunne, Roberts, Samuelson (1989) and Evans (1987). For ICPT project countries see Haddad et al., (1990), Roberts (1989), and Tybout (1989).

economy-wide rates of turnover. Finally, the coefficients are sensitive to the sample period chosen, possibly reflecting hysteresis effects.

Pursuing the issue further, Backenezos (1989) used the Colombian panel to fit industry-specific cost functions jointly with a Probit function that controlled for selectivity due to exit. She found that exiting plants were indeed less efficient than continuing plants, just as table 4 suggests. However, in most sectors, temporal variations in the import penetration rate were not associated with the probability of failure, and among those sectors where significant correlations were found, there were roughly as many positive correlations as negative ones. In short, although much remains to be done in exploring the dynamics of plant turnover, we have not yet uncovered systematic relationships between entry/exit patterns and exposure to international competition.

### C. The Size Distribution of Plants

Although contemporaneous correlations reveal no strong association between import penetration and entry/exit patterns, foreign competition might still affect the size distribution of plants by inducing size adjustments among incumbents or by inspiring entry or exit with a lag. In turn, given the presence of scale economies, these shifts in size distributions may affect industrial productivity. With these links in mind, we next turn to empirical evidence on the relation between trade regimes and the size distribution of plants.

As Berry (1989) notes, earlier studies have found that larger plants are more likely to be exporters. Similarly, it is sometimes conjectured that imports compete more directly with large plants, given the nature of their

product lines. But I am unaware of published studies that correlate trade policy with the size distribution of plants in developing countries, and this is the issue of relevance to productivity measurement.<sup>34</sup> Two exceptions are provided by the ICPT project.

First, Roberts and Tybout (1990a) compare the plant size distributions in Chile and Colombia, industry by industry, relating contrasts to associated differences in trade regime. To summarize the distribution of plant sizes for industry  $i$ , country  $j$ , year  $t$ , they rank plants by ascending employment level and find the employment levels of plants at the 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, and 90<sup>th</sup> percentiles. This generates five size measures:

$$\ln(\text{EMP}_{k_{ijt}}) = \text{logarithm of the } k^{\text{th}} \text{ percentile of the employment size distribution (} k = 10, 25, 50, 75, 90 \text{)}$$

Each of these measures is regressed on proxies for various types of demand determinants. This can be done exploiting either temporal variation, cross-country variation, or both. Given that the former requires modelling of the dynamics of adjustment, and given that the latter accounts for most of the variation in the data, we consider only the cross-country results here. These are based on industry and country-specific averages of annual values for each variable, and should approximate long-run relationships. Letting bars above variables denote temporal averages, the estimated regressions are:

$$(7) \quad \overline{\text{EMP}}_{ij} = \beta_1 \overline{\ln Q}_{ij} + \beta_2 \overline{\text{ERP}}_{ij} + \beta_3 \overline{\text{TUR}}_{ij} + \beta_4 \overline{\text{TUR}}_{ij} \overline{\text{ERP}}_{ij} + \beta_5 \overline{\text{TUR}}_{ij} \overline{\ln Q}_{ij} \\ + \lambda_i + \mu_j + \epsilon_{ij}$$

---

<sup>34</sup> Econometric studies of this issue are also rare for developed countries. Baldwin and Gorecki (1983) is the only example I am aware of.

where

$\ln Q_{ijt}$  - log of real industry output

$TUR_{ijt}$  - turnover rate. The turnover rate is the sum of the industry's entry and exit rates. These rates are averaged across all years for each industry in each country to get a "long run" value that is specific to each industry in each country.

$ERP_{ijt}$  - effective rate of protection.<sup>35</sup>

Here  $\ln Q$  proxies total demand for the industry's output,  $ERP$  proxies protection from international markets, and  $TUR$  proxies the ease of entry and exit. As suggested by many models of trade with imperfect competition, the sensitivity of size distributions to demand shifts should depend upon the ease of entry and exit. The turnover variable is therefore interacted with  $\ln Q$  and  $ERP$ . Finally, to control for industry-specific technology effects and country-specific conditions, represented by  $\lambda$  and  $\mu$  respectively, industry and country dummies are included.

Table 5 reports the findings. Explanatory variables are listed on the left-hand side of the table and percentiles across the top. Each column summarizes a separate regression. Note that overall, the fit is fairly tight, and both trade patterns and turnover appear to matter a great deal.<sup>36</sup>

---

<sup>35</sup> Given that Chilean protection was essentially uniform across industries during the sample period, cross-sectional variation in this protection measure is due only to Colombia.

<sup>36</sup> Interestingly, the country dummy is insignificant, suggesting that any cross-country contrast in the size distribution is associated with contrasts in the explanatory variables.

Further, controlling for country-wide effects, industry effects, and the level of industry output, higher effective protection rates are associated with larger plant sizes, especially at the low end of the size distribution. These results suggest that demand contraction, factor market effects, and other forces associated with increased import competition apparently dominate any expansionary forces that might come from higher demand elasticities in open economies.<sup>37</sup> Also, the coefficients on the interaction between TUR and ERP are significantly negative, which implies that the size effect of trade exposure is more substantial in low turnover industries. Given that import expansion is associated with output contraction, this is consistent with the theoretical result that more size adjustment occurs when exit is not easy (e.g., Rodrik, 1988a; Buffie and Spiller, 1986). Alternatively, the results may simply mean that the discipline of foreign competition matters more in industries where the discipline of potential entry is less important.<sup>38</sup>

---

<sup>37</sup> Baldwin and Gorecki (1983) found similar effects in Canadian data, although they did not stress them in their analysis.

<sup>38</sup> All of these results hold up if size is measured with output instead of employment. They also hold up if ERP is replaced with import penetration rates and export ratios -- in fact this strengthens them. In regressions based on time series (rather than cross-country) variation in the data, however, no clear pattern emerges. This probably reflects the inability of the model to capture the dynamics of adjustment.

TABLE 5

TRADE POLICY AND THE PLANT SIZE DISTRIBUTION: CHILE VS. COLOMBIA <sup>a</sup>  
(Absolute values of t-statistics in parenthesis)

$$\overline{EMP}_{k_{ij}} = \beta_1 \overline{\ln Q}_{ij} + \beta_2 \overline{ERP}_{ij} + \beta_3 \overline{TUR}_{ij} + \beta_4 \overline{TUR}_{ij} \overline{ERP}_{ij} + \beta_5 \overline{TUR}_{ij} \overline{\ln Q}_{ij} \\ + \lambda_i + \mu_j + \epsilon_{ij}$$

	Percentile (k)				
	10th	25th	50th	75th	90th
$\overline{ERP}$	.244* (3.41)	.352* (2.52)	.361 (1.78)	.332 (1.97)	.368 (1.36)
$\overline{\ln(Q)}$	.296* (2.39)	.422 (1.78)	.545 (1.58)	1.15* (4.03)	1.24* (2.70)
$\overline{TUR}$	14.05* (2.33)	19.08 (1.64)	21.96 (1.31)	43.73* (3.13)	45.28 (2.03)
$\overline{TUR*ERP}$	-.707* (4.45)	-1.05* (3.43)	-1.01* (2.29)	-1.04* (2.84)	-1.11 (1.89)
$\overline{TUR*\ln(Q)}$	-.876* (2.29)	-1.18 (1.62)	-1.41 (1.32)	-2.67* (3.03)	-2.73 (1.93)
Chile Dummy	.003 (.014)	-.038 (.097)	-.113 (.198)	-.517 (1.09)	-.474 (.623)
$\overline{R}^2$	.664	.587	.596	.836	.647

<sup>a</sup>Plant size is measured by employment. Industry dummies were included in the regressions but are not reported. Because of various data problems, the manufacturing industries 311, 312, 314, 353, 354, 361, 372, and 385 are not included in the analysis. This leaves 21 three digit industries in each country to support the regressions.

\*Significantly different from zero at the .05 level using a two-tail test.

source: Roberts and Tybout (1990)

In a related study, Tybout, de Melo and Corbo (1990) compare the 1967 and 1979 Chilean industrial censuses, asking whether sectors that underwent relatively large reductions in effective protection between the census years showed distinctive shifts in their size distribution. They look at the cross-industry Spearman rank correlation between changes in an effective protection measure,  $PROTEC_i = (1+ERP_{i,79})/(1+ERP_{i,67})$ , and changes in the various size percentiles,  $SIZE_{ik} = EMP_{k,79}/EMP_{k,67}$  ( $k = 10, 25, 50, 75, 90, 99$ ). Because these variables are in ratio form, industry-specific factors and general changes in the macro environment should not affect the association between these rankings. Accordingly, this exercise is very similar to the table 5 regressions, except here variation is examined across time rather than across countries.

---

Table 6: Spearman Rank Correlation of Effective Protection Changes With Changes in Size Percentiles (Chile, 1967 vs. 1979)\*

	Percentiles					
	<u>10<sup>th</sup></u>	<u>25<sup>th</sup></u>	<u>50<sup>th</sup></u>	<u>75<sup>th</sup></u>	<u>90<sup>th</sup></u>	<u>99<sup>th</sup></u>
Corr(PROTEC, SIZE <sub>k</sub> )	.251 (1.13)	-.055 (0.25)	.260 (1.17)	.520 (2.67)	.397 (1.89)	.251 (1.13)

\* Absolute values of "t" ratios are in parentheses.

source: Tybout, deMelo and Corbo (1990)

---

The results are reported in Table 6. They weakly confirm the Table 5 finding that higher levels of protection are associated with larger plant sizes, controlling for industry-specific effects and the state of the macroeconomy. However, it should be noted that the result depends upon



whether employment, output, or value-added are used to measure size. The latter two (not reported here) show a negative weakly significant association between protection and size for the lower percentiles, and a positive insignificant association for the higher percentiles. (This implies that labor productivity among small plants tends to improve most in those industries undergoing the most dramatic reductions in effective protection.) Much remains to be done in determining whether the findings of these two studies generalize to other countries and liberalization episodes, but they do cast doubt on the popular conjecture that opening an economy leads to efficiency gains through the exploitation of plant-level scale economies.

#### D. Plant-specific Technologies

In the preceding analysis we have been looking for linkages between trade policy and productivity that are based on plant heterogeneity. Thus far we have been unable to establish a strong link between trade patterns and turnover. We have also seen that, if anything, increases in trade exposure appear to contract plants in terms of employment.<sup>39</sup> So if we are to muster evidence that trade liberalization improves productive efficiency through heterogeneity effects, it must come from change in the technical efficiency of incumbent plants, or from changes in the types of plants that enter and exit. This section argues that there is some evidence of the former, but as yet the

---

<sup>39</sup> In any event, I am unaware of systematic evidence documenting widespread scale economies at the plant level in semi-industrialized countries. Econometric work based on plant-level panel data tends to reveal increasing returns when cost functions are estimated, and decreasing returns when production functions are estimated. Both results are the likely consequence of measurement error and vintage effects.

latter has not been researched.

### Efficiency Frontiers and Related Estimators

Perhaps the most popular approach to documenting plant-specific technologies is based on "efficiency frontiers." The notion is simple. If the production technology  $Y = f(v, t)$  represents the set of "best practice" isoquants translating inputs into outputs, then actual production observed at the  $i^{\text{th}}$  plant will fall short of maximum production by some amount  $a_i = f(v_i, t) - Y_i$ . If the best practice technology can be estimated, one will have obtained not only a measure of returns to scale, but also a set of plant-level inefficiency indices,  $e_i$ . A variety of approaches to estimating  $f(\cdot)$  exist; partial surveys may be found in Schmidt (1985), van den Broek *et al* (1980), and Forsund *et al* (1980).<sup>40</sup>

Pack (1988) notes that among studies of countries pursuing import substitution, large intra-industry differences in productivity are common, as are low average productivity levels relative to the best practice technology (Handoussa, Nishimizu and Page, 1986; Page, 1984; Pack, 1987). He speculates that similar work "in export-oriented countries would reveal considerably smaller intraindustry variation in TFP as well as a better average level of TFP," but stresses that all evidence points in the direction of one-time improvements in the level TFP with trade liberalization, rather than

---

<sup>40</sup> To my view the most interesting developments since these surveys exploit the added flexibility that analysts are afforded by panel data (e.g., Cornwell, Sickles and Schmidt, 1989; Kumbhakar, 1988). Such data allow one to track individual plants through time, isolating a plant-specific parameter without imposing elaborate distributional assumptions on the disturbance terms. It also allows one to control for the fact that efficiency is almost surely correlated with factor inputs, which biases cross sectional estimates of production technologies (Mundlak, 1978).

improvements in the long run rate of TFP growth. Studies by Chen and Teng (1987) and Handoussa, Nishimizu and Page (1986) are consistent with this conjecture. Havrylyshyn (1990) is less cautious in his assessment. After reviewing several studies applying efficiency frontier to LDCs (Pitt and Lee, 1981; Nishimizu and Page, 1982; Page, 1984) he concludes that they generally "found strong empirical evidence of a positive effect of trade policy liberalization."

Further support for the conjecture that trade liberalization improves technical efficiency may be found in Tybout et al (1990), where Chilean industrial census data from an import-substituting period (1967) and an outward-oriented period (1979) are compared. Tests for the effects of liberalization are based on the following observation: If exposure to foreign competition improves average efficiency and causes plants below minimum efficient scale to exit, then the estimated production technology should show an increase in its intercept, a reduction in estimated returns to scale, and a reduction in residual variation. Rather than use efficiency frontiers to look for these patterns, econometric attention is devoted to correcting for measurement error in capital stocks and missing data (c.f. Tybout, 1990). It is found that, although no more than half of the three digit industries registered overall productivity gains, the ones which showed the most sign of improvement tended to be those which underwent the largest reductions in effective protection.

Thus far, although some studies have included "age of plant" as an explanatory variable, very little has been done to study the importance of systematic shifts in the size and age distribution of plants. Until this is done, we will not know how important the turnover patterns documented in

Tables 3, 4 and 5 are in terms of their effect on productivity. Nor will we know whether the nature of entering and exiting plants depends upon the prevailing trade regime as, for example, when uncertainty affects technology choice. Short of massive engineering studies, the most promising approach to the difficult issue of plant-level technologies lies in cohort-specific analysis of panel data. This not only affords the researcher an opportunity to control for vintage effects, it permits estimation of learning curves, and analysis of the exit decision.

#### IV. CONCLUDING REMARKS

##### A. Productivity Measurement

In the past decade, there has been a growing realization that traditional Tornqvist indices of productivity growth actually pick up much more than innovation, scale economies, and movement to the efficient frontier. If there is one conclusion that emerges with force from recent work, it is that we should approach the reported figures with skepticism. Problems of measurement error, disequilibria, and aggregation bias can easily create the illusion of trends and correlations that have no basis in the economic processes we hope to capture.

These observations are dispiriting, but they have helped to inspire new ways of thinking about productivity growth and new approaches to looking for it. In this paper I have reviewed two new directions. The first is generally concerned with salvaging sectoral/industrial level calculations by correcting for scale economies, adjustment costs, and/or non-competitive pricing. Although these approaches still suffer from significant measurement problems and aggregation bias, they give some sense for the robustness of productivity

growth series to violations of the littany of assumptions. They also have the obvious advantages that they are based on easily accessible data, and they are designed to describe broad trends. The second new direction I have discussed concerns the role of plant heterogeneity in shaping sectoral productivity growth. Except for work on efficiency frontiers, this strand of the literature is in its infancy, so many of the techniques are still quite rudimentary. Nonetheless, they give a crude sense for the importance of entry, exit, and heterogeneity in shaping productivity growth patterns, as well as some specifics on the nature of aggregation bias in industry-level studies.

#### **B. Linking Trade Regimes and Productivity**

Throughout the discussion of new approaches to productivity measurement, performance measures have been examined for correlation with crude indices of trade regime. In view of the diverse, ambiguous theoretical literature on the trade/productivity link, it should surprise no one that stable, predictable correlations have not emerged. Nonetheless, in some countries and during some subperiods, there is some association between trade flow patterns and indices of productivity growth at the industry level, even after correcting for several measurement problems. Also, we may tentatively conclude that the effects of trade regimes on productivity growth are inter-related with market concentration, although the nature of this association is itself unstable.

Digging deeper, the lack of stable correlations in sectoral and industry-level data is matched by a surprising diversity in the processes of entry, exit and scale adjustment. In some economies, a good deal of output fluctuation appears to come from the creation and death of plants, whereas in

others the incumbent plants are what matter. (Cross-country differences in institutions and the degree of uncertainty are possible explanations.) Given that there is considerable variation in size and labor productivity across these plant types, this is one reason the sectoral and industry-level analyses differ. The ICPT project has focussed on linking entry, exit and adjustments in scale and technical efficiency with exposure to trade regime; thus far it appears that exposure to increased foreign competition is not closely linked with entry/patterns, tends to induce reductions in plant size, and may cause some improvements in technical efficiency.

## Bibliography

- Abbott, T., Z. Griliches, and J. Hausman (1989) "Short-run Movements in Productivity: Market Power versus Capacity Utilization, mimeo, Harvard U., 1989.
- Backenezos, C. (1989) "Import Discipline and Industry Rationalization in the Colombian Manufacturing Sector," Pennsylvania State U., processed.
- Balassa, B. (1985) "Exports, Policy Choices, and Economic Growth in Developing Countries After the 1973 Oil Shock," Journal of Development Economics, pp. 23-35.
- Baldwin, J. R. and P. K. Gorecki (1983) "Trade, Tariffs and Relative Plant Scale in Canadian Manufacturing Industries' 1970-1979," Economic Council of Canada, Discussion Paper No. 232.
- Baldwin, R. (1989), "Sunk-Cost Hysteresis," Cambridge, MA, NBER Working Paper Series, No. 2911.
- Baldwin, R. and P. Krugman (1989) "Persistent Trade Effects of Large Exchange Rate Shocks," Quarterly Journal of Economics, pp. 635-654.
- Berndt, E. and M. Fuss (1986) "Productivity Measurement with Adjustments for Variations in Capacity Utilization and other Forms of Temporary Equilibrium," Journal of Econometrics, 33, pp. 7-29.
- Berry, A. (1989) "Firm or Plant Size in the Analysis of Trade and Development," forthcoming in G. Helleiner, ed., Trade Policy, Industrialization and Development: New Perspectives.
- Buffie, E. and P. Spiller (1986) "Trade Liberalization in Oligopolistic Industries," Journal of International Economics, pp. 65-81.
- Caballero, R. and R. Lyons (1989) "Internal Versus External Economies in European Industry," Department of Economics, Columbia University, Discussion Paper Series No. 427.
- Caballero, R. and R. Lyons (1990) "Externalities and Cyclical Factor Productivity," Department of Economics, Columbia University, Discussion Paper Series No. 467.
- Chavas, J. and T. Cox (1990) "A Non-Parametric Analysis of Productivity: The Case of U.S. and Japanese Manufacturing," American Economic Review, vol. 80 no. 3, pp. 450-464.

- Chen, T. and D. Tang (1987) "Comparing Technical Efficiency Between Import-Substituting and Export-Oriented Foreign Firms in a Developing Country, Journal of Development Economics, 26, pp. 277-289.
- Chenery, H., S. Robinson, and M. Syrquin (1986) Industrialization and Growth: A Comparative Study, New York: Oxford University Press.
- Corden, M. (1974) Trade Policy and Economic Welfare. Oxford: Clarendon Press.
- Cornwell C., R. Sickles, and P. Schmidt (1988) "Production Frontiers with Cross-Sectional and Time Series Variation in Efficiency Levels," Michigan State University, processed.
- Denny, M. and M. Fuss (1983) "A General Approach to Intertemporal and Interspatial Productivity Comparisons," Journal of Econometrics, 23, pp. 315-330.
- Diamond, P., D. McFadden and M. Rodriguez (1978) "Measurement of the Elasticity of Factor Substitution and Bias in Technical Change," in M. Fuss and D. McFadden, eds., Production and Economics: A dual Approach to Theory and Application, vol 2, Amsterdam: North-Holland.
- Dixit, A. (1989a) "Hysteresis, Import Penetration, and Exchange Rate Pass-Through," Quarterly Journal of Economics, vol. 104 No. 2 May, pp. 207-228.
- Dixit, A. (1989b) "Entry and Exit Decisions Under Uncertainty," Journal of Political Economy, pp. 620-638.
- Domowitz, I., G. Hubbard and B. Peterson (1986) "Business Cycles and the Relationship between Concentration and Price-Cost Margins," and Journal of Economics, Spring, pp. 1-17.
- Domowitz, I., G. Hubbard and B. Peterson (1988) "Market Structure and Cyclical Fluctuations in U.S. Manufacturing," Review of Economics and Statistics, pp. 55-66.
- Dunne, T., M. Roberts, and L. Samuelson (1989) "The Growth and Failure of U.S. Manufacturing Plants," Quarterly Journal of Economics, pp. 671-698.
- Edwards, S. (1989) "Openness, Outward Orientation, Trade Liberalization, and Economic Performance in Developing Countries," World Bank PRE Working Paper no. 191.
- R. Ericson and A. Pakes (1987) "Empirical Implications of Alternative Models of Firm Dynamics," University of Wisconsin, SSRI Workshop Series No. 8803.



- Evans, D. (1987) "Tests of Alternative Theories of Firm Growth," Journal of Political Economy, 95, pp. 657-674.
- Forsund, F., K. Lovell, and P. Schmidt (1980) "A Survey of Frontier Production Functions and of Their Relationship to Efficiency Measurement," Journal of Econometrics, 13, pp. 5-25.
- Fuss, M. and L. Waverman (1986) "The Canada-U.S. Auto Pact of 1965," NBER Working Paper no. 1953.
- Griliches, Z. and J. Mairesse (1983) Comparing Productivity Growth: An Exploration of French and U.S. Industrial and Firm Data," European Economic Review, 21, pp. 89-119.
- Grossman, G. and E. Helpman (1989) "Endogenous Product Cycles," Foerder Institute for Economic Research, Working Paper 10-89, Tel Aviv, Israel.
- Grossman, G. and E. Helpman (1990) "Comparative Advantage and Long Run Growth," American Economic Review, September, pp. 796-815.
- Haddad, M., B. Horton, and J. de Melo (1990) "Entry, Exit, Competition and Productivity in the Chilean Industrial Sector," The World Bank.
- Hall, R. (1986) "Market Structure and Macroeconomic Fluctuations," Brookings Papers on Economic Activity, 2, pp. 285-322.
- Hall, R. (1988a) "The Relation between Price and Marginal Cost in U.S. Industry," Journal of Political Economy, October, pp. 921-947.
- Hall, R. (1988b) "Increasing Returns: Theory and Measurement With Industry Data," mimeo prepared for NBER Program on Economic Fluctuations, October.
- Handoussa, H., M. Nishimizu, and J. Page (1986) "Productivity Change in Egyptian Public Sector Industries after the 'Opening'," Journal of Development Economics, 20, pp.53-74.
- Harrison, A. (1990) "Productivity, Imperfect Competition, and Trade Liberalization in Cote d'Ivoire," Washington, D.C., World Bank PRE Working Paper No. WPS 451.
- Havyrlyshyn, O. (1990) "Trade Policy and Productivity Gains in Developing Countries: A Survey of the Literature," The World Bank Research Observer, vol 5 no. 1, pp. 1-24.
- Helpman, E. (1990) "The Noncompetitive Theory of International Trade and Trade Policy," in World Bank, Proceedings of the World Bank Annual Conference on Development Economics, 1989.

- Horstmann, I. and J. R. Markusen (1986) "Up the Average Cost Curve: Inefficient Entry and the New Protectionism," Journal of International Economics pp. 225-48.
- Hulten, C. (1986) "Productivity Change, Capacity Utilization, and the Sources of Efficiency Growth," Journal of Econometrics, 33, 1986.
- Jovanovic, B. (1972) "Selection and the Evolution of Industry," Econometrica, pp. 649-670.
- Jorgenson, D. and Z. Griliches (1967) "The Explanation of Productivity Change," Review of Economic Studies, pp. 249-283
- Jovanovic, B. and S. Lach (1989) "Entry, Exit and Diffusion with Learning by Doing," American Economic Review, vol. 79 no.4, September, pp. 690-699.
- Kim, Y. and J. Kwon (1977) "The Utilization of Capital and the Growth of Output in a Developing Economy: The Case of S. Korean Manufacturing," Journal of Development Economics, 4, pp. 265-278.
- Krueger, A. and B. Tuncer (1982) "Growth of Factor Productivity in Turkish Manufacturing Industries," Journal of Development Economics, 11, pp. 307-25.
- Krugman, P. (1986) "New Trade Theories and the Less Developed Countries," in G. Calvo, ed., Debt, Stabilization and Development: Essays in Honor of Carlos Diaz-Alejandro. New York: Basil Blackwell.
- Kwon (1986) "Capacity Utilization, Economies of Scale and Technical Change in the Growth of Total Factor Productivity: An Explanation of South Korean Manufacturing Growth," Journal of Development Economics, 24, pp. 75-89.
- Kumbhakar, S. (1988) "The Specification of Technical and Allocative Inefficiency in Stochastic Production and Profit Functions," Journal of Econometrics, 34, pp. 335-348.
- Lambson, V. (1989) "Industry Evolution with Sunk Costs and Uncertain Market Conditions," University of Wisconsin, SSRI Working Paper no. 8904.
- Lucas, R. (1988) "On the Mechanics of Economic Development," Journal of Monetary Economics, July, pp. 3-42.
- Martin, J. and J. Page (1983) "The Impact of Subsidies on LDC Industry: Theory and Empirical Test," Review of Economics and Statistics, 65, pp. 608-617

- Morrison, C. (1986) "Productivity Measurement with Non-Static Expectations and Varying Capacity Utilization: An Integrated Approach," Journal of Econometrics, 33, pp. 51-74.
- Morrison, C. (1989) "Unraveling the Productivity Growth Slowdown in the U.S., Canada, and Japan: The Effects of Subequilibrium, Scale Economies and Markups," Cambridge MA, NBER Working Paper No. 2993.
- Mundlak, Y. (1978) "On the Pooling of Time Series and Cross Section Data," Econometrica 46, pp. 69-85.
- Nelson (1981) "Research on Productivity Growth and Productivity Growth and Productivity Differences: Dead Ends and New Directions," Journal of Economic Literature, September, pp. 1029-1064.
- Nishimizu, M. and S. Robinson (1984) "Trade Policies and Productivity Change in Semi-Industrialized Countries," Journal of Development Economics, vol. 16, September/October 1984, pp. 177-206.
- Nishimizu, M. and J. Page (forthcoming) "Trade Policy, Market Orientation, and Productivity Change in Industry," in de Melo and Sapir, eds., Trade Theory and Economic Reform: North, South and East -- Essays in Honor of Bela Balassa, Basil-Blackwell.
- Otha, M. (1975) "A Note on the Duality Between Production and Cost Functions: Rate of Returns to Scale and Rate of Technical Progress," Economic Studies Quarterly, 25, pp. 63-65.
- Pack, H. (1988) "Industrialization and Trade," in H. Chenery and T.N. Srinivasan, eds., Handbook of Development Economics, vol. 1, Amsterdam: North-Holland.
- Pack, H. (1989) "Learning and Productivity Change in Developing Countries," forthcoming in G. Helleiner, ed., Trade Policy, Industrialization and Development: New Perspectives.
- Page, J. (1984) "Firm Size and Technical Efficiency: Application of Production Frontiers to Indian Survey Data," Oxford Economic Papers, 32, pp. 19-39.
- A. Pakes and R. Ericson (1987) "An Alternative Theory of Firm Dynamics," Department of Economics, Columbia University.
- Pakes, A. and Z. Griliches (1984) "Estimating Distributed Lags in Short Panels with an Application to the Specification of Depreciation Patterns and Capital Stock Constructs," Review of Economic Studies, 51, pp. 243-62.
- Pitt, M. and L. Lee (1981) "The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry," Journal of Development Economics, 9, pp. 43-64.

- Roberts, M. (1989) "The Structure of Production in Colombian Manufacturing Industries," unpublished paper, The World Bank.
- Roberts, M. and J. Tybout (1990a) "Size Rationalization and Trade Exposure in Developing Countries," forthcoming in R. Baldwin, ed., Empirical Studies of Commercial Policy, U. Chicago Press for NBER.
- Roberts, M. and J. Tybout (1990b), "Plant Heterogeneity and Industrial Growth: The Role of Entry and Exit," Washington, D.C., The World Bank.
- Rodrik, D. (1988a) "Imperfect Competition, Scale Economies and Trade Policy in Developing Countries," in R. Baldwin ed., Trade Policy Issues and Empirical Analysis, U. Chicago Press for NBER.
- Rodrik, D. (1988b) "Closing the Technology Gap: Does Trade Liberalization Really Help?" forthcoming in G. Helleiner, ed., Trade Policy, Industrialization and Development: New Perspectives.
- Schmidt, P. (1985) "Frontier Production Functions," Econometric Reviews, 4 pp. 289-328.
- Shapiro, M. (1987) "Measuring Market Power in U.S. Industry," NBER Working Paper No. 2212.
- Slade, M. (1986) "Total Factor Productivity Measurement when Equilibrium is Temporary: A Monte Carlo Assessment," Journal of Econometrics, 33, pp. 75-95.
- Stewart, F. and E. Ghani (1989) "Externalities, Development and Trade," forthcoming in G. Helleiner, ed., Trade Policy, Industrialization and Development: New Perspectives.
- Tybout, J. (1989) "Entry, Exit, Competition and Productivity in the Chilean Industrial Sector," unpublished paper, The World Bank.
- Tybout, J., J. de Melo, and V. Corbo (1990) "The Effects of Trade Reforms on Scale and Technical Efficiency: New Evidence from Chile," forthcoming in Journal of International Economics.
- World Bank (1987) World Development Report 1987. New York: Oxford University Press
- van den Broek, J. F. Forsund, L. Hjalmarsson and W. Meeusen (1980) "On the Estimation of Deterministic and Stochastic Frontier Production Functions," Journal of Econometrics, 13, pp. 117-38.

PREF Working Paper Series

	<u>Title</u>	<u>Author</u>	<u>Date</u>	<u>Contact for paper</u>
WPS620	Have Commercial Banks Ignored History?	Sule Özler	March 1991	S. King-Watson 33730
WPS621	Sensible Debt Buybacks for Highly Indebted Countries	Enrica Detragiache	March 1991	S. King-Watson 33730
WPS622	How Factors in Creditor Countries Affect Secondary Market Prices for Developing Country Debt	Sule Özler Harry Huizinga	March 1991	S. King-Watson 33730
WPS623	World Bank-Supported Adjustment Programs: Country Performance and Effectiveness	Vittorio Corbo Patricio Rojas	March 1991	A. Oropesa 39075
WPS624	Choosing Policy Instruments for Pollution Control: A Review	Gunnar S. Eskeland Emmanuel Jimenez	March 1991	A. Bhalla 37699
WPS625	How Trade and Macroeconomic Policies Affect Economic Growth and Capital Accumulation in Developing Countries	Ramon Lopez	March 1991	K. Cabana 37946
WPS626	The Macroeconomics of the Public Sector Deficit: The Case of Colombia	William Easterly	March 1991	R. Luz 39059
WPS627	The Role of Institutions in Poverty Reduction: A Focus on the Productive Sectors	Sharon L. Holt	March 1991	WDR Office 31383
WPS628	The Indonesian Family Planning Program: An Economic Perspective	Dov Chernichovsky Henry Pardoko David De Leeuw Pudjo Rahardjo Charles Lerman	March 1991	O. Nadora 31091
WPS629	An Atheoretic Evaluation of Success in Structural Adjustment	Patrick Conway	March 1991	D. Ballantyne 37947
WPS630	The Spirit of Capitalism and Long-run Growth	Heng-fu Zou	March 1991	A. Bhalla 37699
WPS631	The Macroeconomics of the Public Sector Deficit: The Case of Morocco	Riccardo Faini	March 1991	R. Luz 34303
WPS632	The Macroeconomics of the Public Sector Deficit: The Case of Argentina	Carlos Alfredo Rodriguez	March 1991	R. Luz 34303

**PRE Working Paper Series**

	<b><u>Title</u></b>	<b><u>Author</u></b>	<b><u>Date</u></b>	<b><u>Contact for paper</u></b>
WPS633	The Macroeconomics of the Public Sector Deficit: The Case of Thailand	Virabongse Ramangkura Bhanupongse Nidhiprabha	March 1991	R. Luz 34303
WPS634	Trends in Developing Country Exports, 1963-88	Bela Balassa	March 1991	WDR Office 31393
WPS635	Exchange Rates and Foreign Trade in Korea	Bela Balassa	March 1991	C. Cuskelly- Young 39413
WPS636	Economic Integration in Eastern Europe	Bela Balassa	March 1991	C. Cuskelly- Young 39413
WPS637	Poverty in Poland, 1978-88	Branko Milanovic	March 1991	WDR Office 31393
WPS638	Researching the Trade-Productivity Link: New Directions	James Tybout	March 1991	D. Ballantyne 37947